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ABSTRACT

To assess the impact of TICCIT upon the educational process, the Educational Testing Service (ETS) conducted an evaluation comparing the effects of TICCIT and traditional instruction on community college math and English students during the demonstration period covering the first year and a half of full TICCIT implementation. Data were collected from community colleges in Phoenix, Arizona, and Alexandria, Virginia; observations made after the initial evaluation include those from Brigham Young University. Results show that positive achievement results consistently occurred in both math and English applications. Students in mainline TICCIT English classes scored significantly higher on objective tests of writing skills and also scored better on essay tests than lecture students. In five of the six different math courses in which TICCIT was used, students on TICCIT sored significantly higher on posttests than did their counterparts in lecture sections. The evaluation and subsequent experience with TICCIT has shown that its effect upon students, especially the effect upon completion rates, is very highly dependent upon the environment in which it is implemented. This paper presents an overview of the background and design of TICCIT, a summary of data from the ETS evaluation, and the developer's view of the data and their implications. (Author/VT)

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TICCIT APPLICATIONS IN HIGHER EDUCATION:

EVALUATION RESULTS

by

Michael C. Jones

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TICCIT APPLICATIONS IN HIGHER EDUCATION: EVALUATION RESULTS

Michael C. Jones
Hazeltine Corporation

INTRODUCTION

Full-scale operation of the TICCIT™* computer based instructional system began in the 1975-76 academic year. The TICCIT system departed substantially not only from traditional classroom instruction but also from the adjunctive mode of instruction in which many other CAI systems had operated. In order to assess the impact of TICCIT upon the educational process, the Educational Testing Service (ETS) conducted an evaluation comparing the effects on community college math and English students of TICCIT and traditional instruction during the demonstration period covering the first year and a half of full TICCIT implementation. The data collected by ETS at community colleges in Phoenix, Arizona, and Alexandria, Virginia, and observations after the initial evaluation, including data from TICCIT applications at Brigham Young University, demonstrate that even in its initial period of operation students on TICCIT learn very well; in fact, in almost every case students in "mainline" TICCIT courses learn significantly better than comparable students in traditional lecture classes.

Positive achievement results consistently occur in both math and English applications. Students in mainline TICCIT English classes scored significantly higher on objective tests of writing skills and also scored better on essay tests than lecture students. Likewise, in five of the six different math courses in which TICCIT was used during the evaluation, students on TICCIT scored significantly higher on posttests than did their counterparts in lecture sections. Not only did the math students perform better on posttests measuring cumulative learning, they also achieved higher scores for topical tests administered during the term to evaluate immediate learning.

The evaluation and subsequent experience with TICCIT has shown that its effect upon students, especially the effect upon completion rates, is very highly dependent upon the environment in which it is implemented. The most important aspect of the environment appears to be the manner

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* TICCIT (Time-shared, Interactive, Computer-Controlled Information Television) is a trademark of Hazeltine Corporation.

in which the instructor manages student interaction with the system. In most TICCIT mainline English classes instructors generally took an active role in diagnosing problems, assigning special work, and conducting small discussion groups to solve common problems. Such efforts resulted in completion rates during the demonstration period that approached those found with the lecture sections. As experience with the system increased, completion rates with the mainline English application surpassed the rates found in lecture, the TICCIT rates generally in the range of 70% to 90%. Similar results were found in the few math courses that were also conducted in a similar manner; the rates for TICCIT classes managed by an instructor familiar with the TICCIT system also surpassed traditional classroom rates. However, during the evaluation none of the math classes included management procedures similar to those found in English. Completion rates for math in those TICCIT courses were considerably lower than lecture rates. A slight negative impact upon achievement was also found in TICCIT English classes that used TICCIT adjunctively, although the completion rates were close to those of lecture sections. From the observations of TICCIT so far, it appears fair to conclude that the individualized TICCIT instruction will have a significantly positive effect upon student achievement and that student completion rates are affected by the level of management introduced by the TICCIT instructor, with rates higher than lecture rates possible with a comprehensive management program.

The remainder of this paper presents an overview of the background and design of TICCIT, a summary presentation of data from the ETS evaluation, and the developer's view of the data and their implications.

BACKGROUND

In 1971, the Office of Technological Innovations in Education of the National Science Foundation, in order to investigate the impact of computer-assisted instructional systems upon community college education, contracted with the MITRE Corporation to develop and demonstrate the TICCIT™ (Time-shared, Interactive, Computer-Controlled Information Television) system in a community college environment. An independent evaluation of the educational impact of the system was to be conducted by the Educational Testing Service during the 1974-1976 school years.

In order to accomplish its task, the MITRE Corporation engaged instructional design and CAI experts from the University of Texas CAI laboratory and Brigham Young University (BYU) to work closely with its own system engineers in the design,

development, and implementation of the TICCIT CAI system. MITRE engineers were primarily responsible for the hardware and software development; the Institute for Computer Uses in Education at BYU, which then included those who were the key members of the University of Texas development team, directed the development of the freshman-level mathematics and English courses used in the demonstration. Assisting in the specification of those course materials were English and Math faculty from both of the community colleges selected as the demonstration sites, Phoenix (Arizona) College of the Maricopa County Community College District and the Alexandria Campus of the Northern Virginia Community College.

SYSTEM DESCRIPTION

An important aspect of the project was the effort expended developing TICCIT's reliable and inexpensive display system. A brief physical description of the system must include the fact that the system is powered by a pair of mini-computers which direct the retrieval of various types of information, including digital text/graphic displays and audio messages, to be broadcast to the student's terminal, which includes a standard Sony television set, student keyboard, and optional light pen. The use of the television permits an extensive use of color in the digital displays as well as the use of full-color motion video (e.g. video tapes) and broadcast television.

The TICCIT project was concerned not with the development of a new hardware system but of a new instructional system. Therefore, a significant portion of the TICCIT project research was directed towards the development of an effective individualized instructional delivery model. The resulting model is a unique combination of new ideas and highly tested instructional design principles, some of which are briefly described below.

Mainline courseware. TICCIT is not designed to be used as an adjunctive resource to supplement regular classroom instruction but to be used as the primary source of the delivery of instruction. The role of the teacher is intended to be that of manager-advisor, working with individual students in tasks such as selecting goals, diagnosing problems, prescribing special assignments, holding limited classes in subject areas causing particular difficulties, and, in general, providing the motivation required to overcome inherent pacing problems in such an individualized system. TICCIT administers and evaluates all the primary instruction and lesson tests, provides students with inter- and intra-lesson advice concerning learning strategy, and provides instructors with student performance data.

Mastery. The testing on TICCIT requires all students to attain a specified level of achievement in each lesson. Each student spends as little or as much time as necessary to reach that goal; one aim of the system is to provide for each objective enough material at differing difficulty levels to allow students of divergent entry levels to achieve mastery.

Separation of Content and Strategy. The analysis of research conducted in connection with TICCIT and other projects indicated that the effectiveness of a particular learning strategy is independent of subject matter. The model of instruction implemented on TICCIT and found to be most effective in promoting mastery of the types of objectives used in academic course work is based, among other things, on the presentation for each objective of a generality statement, examples of the generality, and practice problems. The example and practice items are present in large numbers, insuring to the student the presence of a divergent set of instances at different difficulty levels. In addition, every generality and instance is further explained in detail through the use of "feedbacks" and "helps."

Not only does the separation of content and strategy provide the student with a consistent learning environment for each objective, but it also eliminates the need for the subject matter expert/author to be involved in lengthy determinations of teaching strategy. The built-in learning strategy makes possible a team approach to authoring, allowing a differentiated staffing scheme for cost-effective courseware production. Those highly trained in subject matter and instructional design perform only creative tasks, such as lesson specifications; routine formatting and data entry are completed by a specialized production staff.

Learner Control. Within the structured design of instruction, the student exercises control over the pace of instruction, the sequence of instruction, and the strategy of the instruction for each objective. From all of the instructional components available, the student chooses the type and quantity he/she wishes to see. The student is assisted in this responsibility by an on-line "advisor" which attempts to inform the student what options would appear to be reasonable based on the student's past performance.

ETS EVALUATION-INTRODUCTION

Although original project plans called for evaluations of costs, technical achievements, and educational impact, the final ETS report is concerned only with the latter. In order to judge the system's impact upon education at the

community colleges, ETS compared students in traditional classes with students in the same courses taught on TICCIT. Because of the mainline nature of the TICCIT system, the comparison was sharply defined; students on TICCIT, although still directed by an instructor, generally received all or nearly all of their instruction on-line, while non-TICCIT students were instructed in the traditional manner, receiving instruction from textbook and lecture. Although the evaluators had no control over class composition, students often chose TICCIT or non-TICCIT sections on what might be considered a semi-random basis, and in the evaluator's estimate, class composition did not appear to create any bias toward either the TICCIT or non-TICCIT condition. The measures of educational impact included student achievement, completion rates, student and faculty attitudes, and student and faculty activities.

At the time this paper was written, the evaluation report was only partially complete. The chapters available included the two most important for purposes of this discussion, student achievement and completion rates. The following two sections summarize the data reported in those two chapters.

STUDENT ACHIEVEMENT

Measures. In order to compare the effects of TICCIT upon cumulative learning, identical posttests were administered to all students finishing the identified math and English courses; differences in test scores between TICCIT and non-TICCIT sections indicated the effect of the TICCIT program upon achievement, with an effect of 4 points representing an approximate difference in outcomes of ten percent of the test's total possible score. For math courses, the evaluation looked not only at the total score across items which tested objectives common to both treatment conditions, but it also examined achievement in terms of subscores for ability levels, such as problem solving ability, and content categories, such as linear equations. For English courses the posttest was divided into two distinct parts, an objective test of writing skills and an essay test.

Because of the apparent different natures of cumulative and immediate learning, the evaluation included provisions for testing immediate learning in the math course. The test for such learning consisted of a topical test to be administered to the students as soon as the material to be tested were completed by the student.

Populations. In reporting the achievement data for English sections, comparisons are not made between the entire group of students enrolling in the two conditions. In both TICCIT and lecture sections, less than the entire group of enrollees finished the course, and neither of the groups that did finish was representative of the entire population enrolled in the respective course. For both conditions, the entrance ability of those finishing was greater than those not finishing. However, compared to each other the groups were similar; therefore, student achievement comparisons are between the students completing English on TICCIT and those completing lecture sections.

In mathematics fewer students completed the course on TICCIT than did with lecture, and the average entrance ability of the students finishing within one academic term was higher than that of the students finishing lecture sections. Therefore, the initial comparison for math post-test achievement results was between the group completing TICCIT within one term and similar students (based on entrance ability) completing lecture classes. For additional posttest analysis, the population was substantially enlarged by including in the analysis scores of the many students completing TICCIT courses during a second academic term. A larger comparison group was also used in the analysis of topical test achievement.

Results -- Math. The tables on the following pages include samples of the pretest and posttest observations of students completing math and English courses. The data presented represent observations within academic terms. The analyses for both math and English were completed on a class-by-class basis, but because of the large number of TICCIT math students who had pretests in one term but completed the course and posttest in a subsequent term, math achievement results were also analyzed at the course level ignoring the time constraints of individual terms. The first table presents data from the math courses. The analysis for the single class data (completions within a term), taking entrance ability into account, shows a positive TICCIT impact on achievement in eight of the eleven cases, two cases showing significant positive impact. However, as stated above an analysis was also completed which dropped the time constraints of a single academic term to permit the inclusion of the scores of many math students who re-enrolled in a second term to complete the course. The inclusion of these students not only increased the number of pretest-posttest observations but also improved the size of the applicable populations. For example, in the fall quarter of beginning algebra at Phoenix the mean pretest score for students completing TICCIT courses within one term was 44.86 while the mean pretest score for those who began the course in the fall term but completed during the spring term was 33.92, nearly one standard deviation lower.

TABLE 1

ACHIEVEMENT SUMMARY
MATH
Academic Year 1975-76

Course	Term	Comparison Group	All Pretests N	All Pretests Mean	All Posttests N	All Posttests Mean	Pretest-Posttest Observations Pretest N	Pretest-Posttest Observations Pretest Mean	Pretest-Posttest Observations Posttest N	Pretest-Posttest Observations Posttest Mean
Phoenix										
007	Fall	Total	415	37.26	182	39.42	152	41.80	152	39.32
		TICCIT	161	35.32	27	44.26	22	44.86	22	43.32
		Lecture	254	38.49	155	38.58	130	41.28	130	38.64
	Spring	Total	332	36.24	181	38.96	172	39.05	172	38.78
		TICCIT	110	36.15	35	40.57	32	40.06	32	40.09
		Lecture	222	36.28	146	38.58	140	38.82	140	38.49
Alexandria										
31	Fall	Total	195	31.72	58	38.90	52	38.19	52	39.27
		TICCIT	90	31.56	9	45.33	9	47.22	9	45.33
		Programmed	47	29.74	7	34.86	4	36.50	4	34.75
		Lecture	58	33.59	42	38.19	39	36.28	39	38.33
	Winter	Total	105	30.00	62	38.53	46	34.09	46	39.07
		TICCIT	41	27.29	25	40.00	21	34.33	21	40.86
		Programmed	33	32.21	16	38.56	10	34.00	10	39.10
		Lecture	31	31.23	21	36.76	15	33.80	15	36.53
	Spring	Total	130	29.01	38	38.83	32	38.37	32	38.56
		TICCIT	41	30.12	11	40.36	9	41.33	9	40.56
		Programmed	58	26.14	16	36.44	14	33.21	14	35.79
		Lecture	31	32.90	11	40.73	9	43.33	9	40.89

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TABLE 2

ACHIEVEMENT SUMMARY
ENGLISH
Calendar Year 1976

Phoenix

Term	Comparison Group	All Pretests N	All Pretests Mean	All Posttests N	All Posttests Mean	Pretest-Posttest Observations Pretest N	Pretest-Posttest Observations Pretest Mean	Pretest-Posttest Observations Posttest N	Pretest-Posttest Observations Posttest Mean
Objective Test of Writing Skills									
Spring	Total	283	23.17	147	26.39	131	24.49	131	26.73
	TICCIT	126	21.87	49	27.94	47	24.30	47	27.81
	Lecture	157	24.22	98	25.61	84	24.60	84	26.12
Fall	Total	479	22.89	318	26.31	276	23.62	276	26.26
	TICCIT	182	23.99	123	27.45	87	25.37	87	27.53
	Lecture	297	22.22	195	25.60	189	22.82	189	25.67
Essay Test									
Spring	Total	300	2.02	145	2.14	137	2.08	137	2.14
	TICCIT	124	1.96	49	2.26	47	2.10	47	2.26
	Lecture	176	2.07	96	2.08	90	2.08	90	2.08
Fall	Total	506	1.91	320	2.09	297	1.99	297	2.08
	TICCIT	208	1.88	117	2.08	99	1.95	99	2.07
	Lecture	298	1.94	203	2.10	198	2.01	198	2.09

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When all six of the different math courses were so analyzed, the results indicated that three of the four courses at Phoenix and both courses at Alexandria demonstrated an overall significantly positive TICCIT effect upon achievement. In a comparison between TICCIT and programmed instruction, the TICCIT effect was positive and approached accepted limits of significance. That there were fewer items on the posttest common to the two conditions (38 instead of 44) would lead to an expectation of a lower effect than that between TICCIT and lecture. The positive effect was obtained for both day and evening classes.

In these analyses, there are two interactions which should be mentioned. For beginning algebra at Phoenix, the evening division contributed the major effect to the achievement gain, demonstrating a gain equivalent to ten percent of the possible total score. A similar positive effect was found for the day division students at Alexandria.

The ability and content subscores for math posttests were examined in an attempt to discover whether TICCIT might be strong or weak in certain areas of study. Table 3 lists the ability levels and content categories analyzed on the basis of various posttest items. As might be expected, the number of items for each type of ability or category is small. ETS analysis indicated that although some of the subscores did approach reliability for group measures, most did not, making any outcomes more descriptive than conclusive. Few of the categories resulted in significant effects; only two significant effects were repeated across terms, and both were in favor of TICCIT. Solution of routine problems as an ability level involved positive TICCIT effects in every case and significant effects in two courses. The other repeated significant positive effect involved the content category of equations. These specific strengths must be attributed to the depth of coverage of topics and extent of practice capabilities. In general, in those areas of the math curriculum considered to require the highest ability and to be most advanced, TICCIT outcomes showed consistently positive effects.

The topical tests administered and the analysis of the effect of TICCIT are shown in Table 4. Generally, the effects follow the pattern found in posttests. Although only one of the results was significant at acceptable levels, in four of the cases the results show a sizeable point difference which represents a positive TICCIT effect equivalent to ten percent of the total possible score on the tests. Another indication of the positive impact of TICCIT upon achievement is the fact that these results apply to a wider range of students than those taking posttests since the topical tests were administered earlier in the term.

TABLE 3

ABILITY LEVEL

- Factual recall
- Manipulation
- Solution of routine problems
- Demonstration of concept comprehension

CONTENT CATEGORY

1. Arithmetic
2. Algebra
   (a) Simplifying, including properties of and computations with signed numbers and complex numbers
   (b) Equations, including substitutions, equivalent equations, solution of equations, and word problems
   (c) Exponents, radicals, and logarithms
   (d) Factoring, multiplying, and dividing algebraic expressions including quadratics
   (e) Number line and coordinate plane
   (f) Inequalities, absolute value, and sets including solution sets
   (g) Sequences, arithmetic and geometric progressions
   (h) Permutations and combinations, binomial theorem

TABLE 4

ACHIEVEMENT RESULTS: ANALYSIS FOR IMMEDIATE LEARNING
Alexandria and Phoenix
Math Courses
Academic Year 1975-76

Course	Term	Topical Test	Number of Students	Multiple Correlation	Independent Variables	Regression Weights	Value of t-statistic
007	Spring Semester	Linear Equations	72	.71	TICCIT(1) Lecture(0)	2.76	3.16**
108	Spring Semester	Algebraic Expressions	47	.60	TICCIT(1) Lecture(0)	2.27	1.42
31	Fall Quarter	Linear Equations	63	.62	TICCIT(1) Lecture(0)	.41	.35
31	Winter Quarter	Linear Equations	47	.63	TICCIT(1) Lecture(0)	2.17	1.83
31	Spring Quarter	Linear Equations	27	.75	TICCIT(1) Lecture(0)	2.61	1.61
32	Spring Quarter	Algebraic Expressions	52	.30	TICCIT(1) Lecture(0)	-2.09	-1.61

**p < .01

Results -- English. Only cumulative learning as indicated through posttests was analyzed for achievement effects in English courses. The posttests themselves were divided into two parts. An objective test called for responses to multiple-choice questions about grammar and writing structure; the second part of the test required the students to write an essay on a given topic.

As with completion rates, the results for achievement in English appear much more complicated than those for math, largely because of the entry into the analyses of various interaction terms and seemingly inconsistent results. The initial analysis involved highly mixed results, with six of the ten cases showing negative TICCIT effects. Four of the cases were significant but highly unique: a positive effect on objective scores at Phoenix, a negative effect on objective scores at Alexandria, a positive effect on the essay test at Alexandria, and a negative essay effect at Phoenix. Only analysis combining these data with various interactions makes the result any clearer.

At Phoenix the combined analysis does show a positive impact on achievement based on the objective test, across both terms. In the first term the effect was dependent upon age and did not appear in the initial analysis. The effect was positive and significant at the mean age (26.5) of the students who completed courses on TICCIT. The effect was still positive, though not significant, at one standard deviation below the mean age (18). The second term at Phoenix also demonstrated the same significant, positive effect for TICCIT, though independent of age. Descriptive evidence for a third term demonstrated that the trend continued.

For the essay tests at Phoenix, there was a difference between day and evening division students. A positive TICCIT effect occurred among day students, yet among evening students there was a significant negative effect, probably attributable to the fact that part-time instructors unfamiliar with TICCIT taught the evening divisions.

The significant negative impact on the objective posttest at Alexandria seemed to be related to entrance ability. For very high ability students (pretest scores one standard deviation above mean) the effect became positive; as pretest scores decreased, the negative TICCIT effect increased. The other significant effect at Alexandria was a sizeable positive effect on the essay scores of the TICCIT evening division students. The ETS evaluation attributes some of this gain to the fact that one instructor for the lecture sections stressed writing skills, sacrificing performance on essay tests. That may be true, but it should be pointed out that such a statement might be true of all TICCIT English sections,

since the TICCIT course as designed clearly stressed writing skills.

To summarize the achievement data for English, it is necessary to discuss the preceding data in light of one additional fact. That fact is that the TICCIT English courses were used in somewhat different contexts at the two colleges. At Phoenix the courses were used in a manner more closely akin to the original "mainline" concept advocated by develcpers than they were at Alexandria. At Phoenix, TICCIT classes generally followed the original course outline, meeting an average of once per week as a class; the Alexandria courses could more accurately be labeled "adjunctive," using TICCIT as an additional resource, albeit very important in terms of the proportion of total student time allocated to the system, to the average three hours per week in the classroom. In that light, it can be said that TICCIT as a mainline instructional resource had a consistently significant, positive impact upon student achievement on the objective posttest of writing skills. Other effects noted for TICCIT were often tied to other variables, primarily differential instructor effects. An adjunctive use of TICCIT appeared to have a negative impact on achievement upon all but higher ability students.

Summary. TICCIT exerts a significant and positive impact upon student achievement. For five out of the six observed math courses significant positive results occurred, often resulting in TICCIT posttest scores at least ten percent higher than lecture, corresponding to two-thirds of a standard deviation. In addition to overall higher achievement on posttests, TICCIT promoted higher achievement in the ability of students to solve routine problems and was equal to lecture in promoting adequate performance in the most advanced content areas of the math curriculum. In four of the six math courses, students in TICCIT courses scored about ten percent higher on topical tests of immediate learning than similar lecture students. In English, the only consistent results for courses comparing TICCIT as designed and lecture likewise demonstrated significant positive effects for TICCIT students, resulting in an estimated difference of five percent in scores on objective tests of writing skills. Except where inexperienced instructors affected results, TICCIT students also scored higher in essay tests.

COURSE COMPLETION RATES

Student completion rates among the various TICCIT applications varies tremendously. There does not appear to be any simple explanation for the variations, but one of the most obvious factors is the environment in which the TICCIT student learns. Because of the self-paced nature of the TICCIT system, the effect of instructor involvement in the learning environment appears to have an even greater impact upon completion than originally thought.

In the original community college implementation, there was no emphasis upon completion as a program outcome; however, early in the demonstration it became apparent that high completion rates would not be achieved without a more structured environment. Therefore, the TICCIT users at BYU established the use of TICCIT in environments which included a weekly scheduled class meeting, small group discussions, individual student/teacher meetings, and other features designed to motivate the student to complete within the academic term.

This model produced completion rates generally higher than in comparable lecture sections at BYU. In math, the average completion rates for classroom instruction was 65%. Classes taught by one of the TICCIT math authors averaged higher rates than the class room rate. Two classes taught by teachers previously unfamiliar with TICCIT were mixed; one had a completion rate of 72%, the other 33%. Rates for TICCIT English classes were also favorable, ranging from 88% to 96%. Those rates exceeded the very liberally-calculated completion rate of 82% for the classroom (the lecture sections did not include in the rate calculation any of a large number of students withdrawing before the third week of class). Clearly, when efforts are expended to obtain high completion rates, it is possible to do so in an environment which attempts to pace students within certain time periods.

Although community college implementations of TICCIT did not generally include such concerted efforts to increase completion rates, the TICCIT English instructors were generally very imaginative in their approaches to directing the TICCIT classes, using class meetings and group discussions, and it was apparent that those efforts did result in completion rates that, although lower than lecture classes at the community college, were significantly higher than those in math classes in which there was basically no effort to pace student learning according to any schedule. In three of the five cases in English there are significant negative impacts upon completion attributable to the TICCIT condition, but they are all at much lower levels than in math. The rates

were generally 10% to 20% lower than classroom completion rates, which ranged from 60% to 75%. The analysis is complicated by the fact that there are several traits exerting some influence on completion and a number of trait-treatment interactions, which, to add to the confusion, often vary when analysis within terms is compared to analysis across terms. Some of the student traits having a significant impact upon completion, regardless of instructional condition, included division of enrollment (in one section, day students had a 45% better chance than evening students of completing an English course), class instructor, and re-enrollment (in three of the five sections, students repeating or continuing a class had a poorer chance of completing than those enrolled for the first time). Contrary to the analysis for math, there was in English some significant interaction between entrance ability as demonstrated on an objective pretest of writing skills and completion rates in TICCIT sections. The interaction did not occur in either tested term at Phoenix College, where TICCIT English was used in a manner more consistent with its original design than at Alexandria, although the term did just reach a significant level upon analysis across both semesters. At Alexandria, where the English courses on TICCIT were used more in connection with additional classroom instruction than originally intended, the interaction appeared in two of the three tested classes, but it did not appear in the analysis across quarters. The interaction indicates that students of very low ability were hindered by TICCIT, but that as entrance ability increases completion chances increase until chances of completing on TICCIT are slightly better than completing a lecture section for the higher ability students in the course.

The math courses at both community colleges were generally implemented without any of the tools discussed above that would tend to motivate pacing within the academic term. Total self-pacing was the rule for math classes; there was no penalty for re-enrolling for the same course in subsequent terms. There appeared to be little or no discussion with individual students concerning the student's learning pace, and there were no group or class discussions. The results of the analysis do show significant treatment effects upon completion. In 10 of the 12 math classes analyzed, significant (at $p < .001$ levels in all but one case) and negative treatment effects were associated with the TICCIT sections; the two remaining sections showed no significant treatment effects. The rates for TICCIT sections were generally about half the size of lecture rates, which were about 40% to 55%. The analysis also indicated that entrance ability was significant in determining completion (regardless of condition) in 10 of the 12 cases. The only

student trait found to interact at a significant level with a particular treatment in a math course was student status. That is, for one math course at Phoenix it was found that part-time students on TICCIT were less likely than full-time students to complete the course. There were no other demonstrated trait-treatment interactions, including none between entrance ability and either treatment. An interaction might have been expected between re-enroll status and the TICCIT condition since many students who re-enrolled in TICCIT sections had only to complete course requirements left unfinished from the previous term. However, no such interaction was found, and in the single case where an analysis of the effect of re-enrollment was made, it was found that 17% of the students enrolled in the particular math section for the second time completed within the term compared to a 15% completion rate for students enrolled in the section for the first time.

CONCLUSIONS

The achievement data consistently demonstrate significant and substantial positive gains for TICCIT students in both math and English. The measure of success for TICCIT was to be its impact upon achievement compared to traditional instructional methods. In that light, it must be said that even in its initial operation, TICCIT was highly successful, teaching math and English students better than was done in traditional classes.

Within the ETS evaluation, it was shown that TICCIT English was most successful in bringing about higher achievement gains and completion rates approaching those of lecture classes. Completion rates at the colleges since the evaluation have improved; in fact, the latest figures showed a TICCIT completion rate (72%) higher than lecture classes. Such data together with the very high completion rates and positive achievement data in the more highly managed environment at BYU show that the use of TICCIT has a substantial and positive impact upon instruction.

Similarly, students in TICCIT math classes performed consistently better on course posttests and on topical tests than their counterparts in lecture sections. Although completion rates for the highly managed environment did surpass lecture rates, the rates for TICCIT math classes within the evaluation context were disappointingly low. Completion was not an outcome highly emphasized during the demonstration, but it was expected that the rates would be similar to those in the lecture classes.

An important question is why the rates in math were so much lower than those for English, especially since the design for each of the courses was basically identical. It has already been suggested that the difference in instructor involvement in student management is the reason for the variable rates. Other possible explanations include the failure of TICCIT adequately to serve the needs of lower ability students. Completion in math did seem to be connected to entrance ability. It is not clear, however, whether the reason for that is the particular math courseware or some inherent characteristic of the system itself.

There is some evidence to indicate that the math courseware used in the demonstration did not serve the needs of those students requiring a large amount of remedial help. TICCIT did include substantial amounts of very basic material, and the course was very successful in math courses at both colleges which were the lowest level courses available. But it does appear that there were simply greater student deficiencies in math than had been anticipated. Moreover, time constraints prevented the completion of any formative evaluation of the materials. In other words, the courseware used in the demonstration was first-attempt material. At BYU, evaluators found that 60% of the lessons were inadequate for BYU students. Opinions from the community college instructors also indicated that the tests were generally too difficult, hindering the progress of many students. Many of the lessons and tests have since been revised to improve observed courseware problems, but it is too early to know what effect upon completion the revisions will have.

The explanation for lower completion rates apparently favored by ETS is that the TICCIT system itself may favor students of high ability to the detriment of low ability students. There is indeed evidence that entrance ability is a factor that must be considered in the analysis of completion rates. For nearly every analysis conducted on completion in both math and English, there were very large and significant correlations between completion and entrance ability. In both TICCIT and lecture courses the group of students completing the course had higher pretest means than the group beginning a course. In only one term in one course, the adjunctive use of TICCIT English, was there an actual interaction between entrance ability and completion. It was shown in that instance that the lower the entrance ability the greater the chance became that a student would not finish because of enrollment in a TICCIT class.

The conclusion that TICCIT is perhaps best suited for those of high entrance ability does not appear to be based upon that interaction term from English. The conclusion

seems to be based upon the observation of differences in pretest means of students finishing on TICCIT and students finishing lecture sections. The differences in the fall terms were particularly large. However, in later terms the differences in pretest mean scores became much smaller, primarily because of the addition in later terms of the scores of students taking more than one term to complete. The effect of this can be seen in the analysis of the fall term of beginning algebra at Phoenix. The pretest mean for students finishing TICCIT was 44.86 while for lecture it was 41.28. Logically, one might conclude that any difference in posttest scores (actual scores for TICCIT and lecture were 40.06 and 38.82, respectively) must be due to the high entrance ability. However, further analysis limiting the comparison to higher ability students (defined in this case by pretest scores greater than or equal to 35) still showed positive achievement effects. Later analysis eliminating the constraint of completions within a term included a sizeable group of students who had completed TICCIT math during the spring semester. The mean pretest score of this group was 33.92, decidedly below the earlier defined high ability level of 35, below the pretest mean of lecture students completing the fall semester (38.64), and below even the mean of the lecture students from the fall who did not finish within one term but also completed in the spring (34.62). Yet this broadening of the applicable entrance ability did not subtract from the overall achievement result. In fact, as mentioned earlier, the inclusion of all the students requiring more than one term to complete increased the impact of achievement results. Although the view of the TICCIT completion and achievement results within a single academic term tends to support an argument for TICCIT suitability only to high ability students, the results across terms weakens the argument with the inclusion of substantial numbers of students with much lower entrance abilities who, nonetheless, add a greater degree of significance to the positive achievement data.

An additional factor which weakens the high entrance capability argument is the topical test analysis. For topical testing, an even broader segment of the student population was included. Unfortunately, no detailed analysis is made of students completing topical tests in terms of entrance ability. The comments in the evaluation imply that the group taking the pretest was more inclusive than the group completing TICCIT but did not include the entire population beginning the course. The students were characterized as those able to make progress towards completion on TICCIT. Again with the enlarged population, there are still substantial achievement gains for TICCIT students in five of the six courses. Although the data is not clear, the implication from the topical test results is that the entrance ability argument must be still further weakened.

The evaluation report's treatment of the topical tests seems to concern itself with the fact that the TICCIT population taking topical tests was still smaller than the population originally enrolling in the course. That fact may in some situations be compelling evidence in support of the contention that TICCIT is better suited to highly capable learners. But the context of this evaluation is a comparison of TICCIT and traditional instruction; therefore, the statement that TICCIT would be suitable only for high ability students implies that the lecture condition has a more positive impact upon those of lower ability. It is clear from evaluation data, however, that the traditional instructional method also exerts a strong bias against the lower ability student. The issue then is not simply whether TICCIT exerts a bias towards low ability students but whether that bias is significantly greater than that already existent in traditional instruction. Without very substantial differences, the statement that TICCIT is suitable for high ability students could not be justified. On the basis of the results of across-term analysis and topical testing discussed above, the developers do not find such differences to justify the conclusion that TICCIT applications should be limited to those involving only highly capable learners.

Further arguments against the general hypothesis that TICCIT is not suitable for students of less than high ability are found in the following observations. First of all, the math courses under consideration were fundamental courses in community colleges with very liberal enrollment policies. A large number of the classes for which data were taken did not qualify as college credit courses but were developmental classes to compensate for pre-college deficiencies. They are necessary and important courses, but it may be difficult to support any general statement concerning high ability students on the basis of observations only from these courses. Perhaps even more interesting is the relationship between two of the courses at Phoenix. Generally, students enroll in math 007 only because they have not demonstrated the entrance ability, as judged by performance on a pretest, required for math 106. By definition, students in 007 would be of lower entrance ability (i.e. lower pretest scores) than those in 106. Yet the analysis for math 007 demonstrated one of the strongest positive effects for TICCIT students.

In short, the developers find in the evaluation satisfying evidence that TICCIT can be successfully applied in learning environments in which there are varied entry abilities. Although entrance ability must be considered in the system's implementation, it is not clear what relationship it does in fact have with completion rates. It would be difficult to prove from the data that there is a causal relationship between entrance ability and completion. It is,

assigned to the lab in a given hour may not have been able even to identify individual students. In short, there appear to have been substantial differences between both the quantity and quality of instructor interaction with math and English students.

It is perhaps understandable that there were differences between the management efforts in math and English. The developers did attempt to provide features in the system, such as various reports concerning individual student progress, but for various reasons no systematic method of handling the management problem was provided. It is to the credit of the colleges themselves that programs were developed in the English courses that did improve student completion rates through better management. The methods implemented, including small group discussions and closer involvement in individual assignments, could and should also be used in mathematics. The possible impact of management was not discussed in the ETS evaluation of math completion rates, possibly because none of the math sections dealt with the problem and because no obvious solutions to the problem were ever suggested or implemented. But because of the basic similarities between the courses, there is reason to believe that similar management efforts would also increase math completion rates. The evaluation did indicate a strong correlation between time spent on-line and the number of math lessons completed. To improve the rate of completion, it would appear then that measures are needed to improve student motivation to spend an adequate amount of time on the system. Further evidence for the efficacy of management efforts is found in the BYU math implementation, discussed earlier in the completion rates section, in which TICCIT completion rates did exceed those of the classroom.

The developers are highly pleased with the results of the evaluation. Very clearly positive achievement results for instruction in English was a result expected by very few people. Yet the results do show that grammar and composition can be taught systematically with positive effects on student writing capabilities. Even in the initial year of implementation of a radically new instructional method, nearly as many students finished the course with TICCIT as with the established instructional method and performed significantly better on achievement tests. As instructors have become experienced with the system, its effectiveness continues to be manifested: completion rates now often exceed those of the classroom. Achievement for math students on TICCIT is equally pleasing. Distracting slightly from that enthusiasm were the lower completion rates found with the math sections within the evaluation. However, the developers find no reason to believe that there is any inherent characteristic of TICCIT instruction that would prohibit completion in math from being equal to that found with English. There is ample evidence, including already improved completion rates, that the management techniques used to improve completion for English classes are just as effective in promoting completion rates in math

of course, possible that some other student trait closely associated with entrance ability, such as general self-motivation capabilities, contributes to the discrepancy in rates. There is, in fact, some evidence within the evaluation to support that contention.

Comparing the completion rates of math to those of the self-paced programmed instruction makes it reasonable to assume that the problem of low completion rates is a generic problem with self-managed instruction. The rates found in TICCIT were comparable to the rates in the self-paced programmed instruction at Alexandria and to the historical rates of similar programs at Phoenix. The evaluation record mentions the problem a number of times, referring, for example, to the fact that many students failed to attend classes regularly, or at all, when pressures from other non-self-paced courses increased. Records of the number of hours spent on-line also indicated that students not completing the course spent fewer hours on the system than the number of hours assigned for classroom usage in the lecture sections. (For example, a study conducted by Alexandria indicated that average usage for students not completing TICCIT sections was approximately 30 hours. The lecture sections met for 50 hours per term.) There is apparently a problem with the management of student progress which greatly contributes to lower completion rates.

The management problem is not surprising, however. From the beginning, the developers understood that such problems existed with self-paced instruction and did attempt to create solutions in advance. The TICCIT math and English courses were both designed to be implemented in an environment in which the instructor took an active role in the management of student progress. The originally defined role of manager-advisor to be assumed by instructors included goal-setting and performance evaluation behaviors. Such a model was implemented much more fully in the English than in the math courses. As has been seen, completion rates in English were higher; in fact, the lowest completion rate in any English course was higher than that for any math section.

The English and math course designs themselves were simply not divergent enough to result in such large completion differences. However, a review of the implementation contexts show striking differences. ETS observed that English instructors took an active role in prescribing study materials, conducting small group discussions about common difficulties, and handling individual student problems. On the other hand, math students had much less instructor contact, and the great majority of contact that did occur was centered on content problems rather than individual progress problems. At Phoenix, students were not even assigned to particular math instructors; consequently, the instructors

comparable to or exceeding those in lecture classes. TICCIT is a very powerful instructional tool, one which should continue to impact the future of educational practices.

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